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METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART VI LOW-POWER OSCILLATOR KLYSTRONS

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METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART VI LOW-POWER OSCILLATOR KLYSTRONS

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Indian Standard

METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART VI LOW-POWER OSCILLATOR KLYSTRONS

0. FOREWORD

0.1 This Indian Standard (Part VI) was adopted by the Indian Standards Institution on 23 June 1981, after the draft finalized by the Electron Tubes Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This standard covers the methods of measurement of low-power oscillator klystrons.

0.3 Methods of measurement of different types of microwave tubes are being covered in a series of standards consisting of the following individual parts :

Part I	Common to all microwave tubes
Part II	Oscillator tubes
Part III	Amplifier tubes
Part IV	Magnetrons
Part V	Parasitic noise
Part VI	Low-power oscillator klystrons
Part VII	High power klystrons
Part VIII	Gas-filled microwave switching devices
Part IX	Backward-wave oscillator tube — 'O' type
Part X	Crossed-field amplifier tubes

0.4 While preparing this standard, assistance has been derived from IEC Pub 235-5 (1972) 'Measurement of the electrical properties of microwave tubes : Part 5 Low-power oscillator klystrons' issued by International Electrotechnical Commission.

0.5 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard (Part VI) describes the methods of measurement of electrical characteristics and related requirements and precautions applicable to low-power oscillator klystrons.

2. TERMINOLOGY

2.1 For the purpose of this standard the terms and definitions given in IS : 1885 (Part IV/Sec 3) - 1970† shall apply.

3. GENERAL REQUIREMENTS AND PRECAUTIONS

3.0 The general requirements and precautions listed in IS : 6134 (Part I) - 1978‡ shall apply in addition to the following.

3.1 Semiconductor Diodes

3.1.1 When output power is examined by means of output from a semiconductor diode it is necessary to calibrate the diode response over the range of power and frequency to be examined. An acceptable method of calibrating the diode response in terms of relative power levels should be used.

3.1.2 *Precaution* — Because semiconductors can be damaged by transients and other causes, it is wise to recalibrate them frequently.

3.2 External Cavities

3.2.1 Standardized cavities and assemblies shall be used in measurements, where applicable.

4. METHODS OF MEASUREMENT

4.1 Reflector Current

4.1.1 *Total Current* — The total reflector current can be measured (a) for non-oscillatory conditions, by a meter in the reflector circuit, or

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*Rules for rounding off numerical values (*revised*).

†Electrotechnical vocabulary : Part IV Electron tubes, Section 3 Microwave tubes.

‡Methods of measurement on microwave tubes : Part I Common to all microwave tubes.

(b) for oscillatory conditions either by a meter in the reflector circuit or by measuring the effect of switching a known high resistance into the reflector circuit. In the latter case, the reflector current can be calculated by measuring the reflector supply voltage change necessary to return the operating frequency to its original value.

4.1.2 *Leakage Current* — The resonator current is reduced to zero by means of grid bias or by opening the cathode circuit, and the reflector current is measured.

4.1.3 *Ion Current* (*Gas Current*) — The value of current determined in the leakage current measurement (*see* **4.1.2**) is subtracted from the value of the total reflector current measured under non-oscillatory conditions. The difference is then considered to be the reflector ion current.

4.2 Power

4.2.0 Provisions of **10.1** of IS : 6134 (Part I)-1978* shall apply in addition to the following.

4.2.1 *Mean RF Output Power* — The tuning controls are adjusted to provide optimum power into the stated load at the reference frequency, and the output power is then measured.

4.3 Pulse Measurements

4.3.1 Provisions of **10.2** of IS : 6134 (Part I)-1978* shall apply.

4.4 Frequency

4.4.0 Provisions of **10.3** of IS : 6134 (Part I)-1978* shall apply in addition to the following.

4.4.1 *Warm-Up Frequency Drift* — This measurement shall be made under stated temperature and for a stated time. The result is the total change of frequency in the stated time interval.

NOTE 1 — It is sometimes necessary to consider the change in power occurring during this measurement.

NOTE 2 — It is frequently desirable to state the beginning of the time interval during which measurements are made.

4.5 Spectrum Width — Provisions of **10.3.1** of IS : 6134 (Part I)-1978* shall apply.

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*Methods of measurement on microwave tubes : Part I Common to all microwave tubes.

4.6 Tuning

4.6.0 Provisions of Appendix A shall apply in addition to the following.

4.6.1 *Frequency Tuning Range* — The result of the measurement is the difference between the frequency at which the output power is greater than a stated value, or than a stated fraction of the optimum output power.

NOTE — In this measurement, optimum power conditions are maintained throughout.

4.6.2 *Mechanical Tuning Range* — The klystron is adjusted to operate at the reference frequency under optimum conditions. The mechanical tuning control only is then adjusted above and below the reference frequency to frequency at which the power is a stated minimum value or stated fraction of the power at the mode centre. The result is expressed as the difference in frequency between these reduced power points.

a) *Mechanical tuning range at fixed voltages* — The klystron is adjusted to operate at the reference frequency under optimum conditions. The mechanical tuning device alone is then adjusted above and below the reference frequency to the frequencies at which the power output is equal to a stated value. The difference between these two frequencies is the mechanical tuning range at fixed voltages.

b) *Optimum mechanical tuning range* — The klystron is adjusted to operate at the reference frequency under optimum conditions. The mechanical tuning device is then adjusted above and below the reference frequency to the frequencies at which the optimum power output is equal to a stated value (for example, the voltages are adjusted to maintain the power output at its optimum value). The difference between these two frequencies is the optimum mechanical tuning range.

NOTE — For reflex klystrons, the reflector voltage alone is adjusted.

4.6.3 *Electronic Tuning Range* — The klystron is adjusted to operate at the reference frequency under optimum conditions. The electronic tuning voltage only is then varied above and below the reference frequency value to the values at which the power is a stated fraction of the power at the mode centre. The electronic tuning range is the difference in frequency between these reduced power points.

4.6.4 *Tuning Sensitivity*

4.6.4.1 *Mechanical tuning sensitivity*

Method 1 : The klystron is adjusted to operate at the reference frequency under optimum conditions. The mechanical tuning control is then adjusted by a stated amount in either direction and the electronic tuning control is adjusted to obtain maximum output power. The new frequency is then measured. The mechanical tuning sensitivity is the measured change of frequency per unit change of the tuning position.

Method 2 : The klystron is adjusted to operate at the reference frequency under optimum conditions. The mechanical tuning control only is then adjusted by a stated amount and the consequential frequency change is noted. The mechanical tuning sensitivity is the measured change of frequency per unit change of the tuner position.

NOTE 1 — If, when the tuning mechanism has been set to give the reference frequency, its travel is limited to less than the amount required for this measurement, the measurement shall be made between the limit point of the tuner mechanism and the position that the mechanism reaches on being adjusted by the required amount towards the mid-band position.

NOTE 2 — In making this measurement, it is necessary to avoid the effect of mechanical tuning hysteresis.

4.6.5 *Electronic Tuning Non-linearity* — The klystron is operated in accordance with the stated conditions. The electronic tuning sensitivity is measured at the mode centre and at two stated frequencies that are equally spaced from the mode centre.

The factor is given by the formula :

$$\frac{S_{\mathrm{m}}-S_{\mathrm{o}}}{S_{\mathrm{o}}}$$

where

S_{o} = the tuning sensitivity at the mode centre.

S_{m} = the larger value of tuning sensitivity obtained at the stated frequencies equally spaced from the mode centre.

This measurement is usually made by a dynamic method, in which the frequency-control voltage that provides the required frequency shift from the mode centre has superimposed upon it, a small sinusoidal voltage of a much higher frequency. The consequential frequency deviation is measured by means of a suitable frequency discriminator or receiver.

The difference between the mode centre value and each of the other two values in turn is measured and the factor is obtained by dividing the larger of the two differences by the mode centre value.

NOTE — For the purpose of this measurement, the point of minimum electronic tuning sensitivity may be used instead of the mode centre.

4.7 Heater Modulation Effect

4.7.1 Provisions of **10.4** of IS : 6134 (Part I)-1978* shall apply.

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*Methods of measurement on microwave tubes : Part I Common to all microwave tubes.

4.8 Frequency-Pulling Figure

4.8.1 Provisions of **4.1** of IS : 6134 (Part II)-1973* shall apply.

4.9 Temperature Coefficient of Frequency

4.9.1 Provisions of **4.3** of IS : 6134 (Part II)-1973* shall apply.

4.10 Spurious Mode Oscillation

4.10.1 Provisions of 5 of IS : 6134 (Part II)-1973* shall apply.

APPENDIX A

(*Clause* 4.6)

A-1. TUNING

A-1.1 Frequency Tuning Range

A-1.1.1 This is obtained by measuring the characteristics of power output versus frequency. It is preferable that the required frequency range be obtained by the use of a single oscillatory mode. However, where a change of mode is permissible, this change should not be considered as constituting a discontinuity of frequency tuning range.

A-2. TUNING SENSITIVITY (Mechanical or Electronic)

A-2.1 The tuning sensitivity may be obtained from a measurement of frequency change with a stated variation of the tuning control (mechanical or electronic) or alternatively as a measurement of tuning control variation for a stated frequency change.

A-2.2 As the tuning sensitivity is not necessarily uniform over the required tuning range, it is recommended that an indication be given as to which part of the range is used in making the measurement, for example, a stated frequency spread centred at the half-power point, over the linear range or in the small-signal range.

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*Methods of measurement on microwave tubes : Part II Oscillator tubes.

A-3. TUNER TORQUE

A-3.1 The tuner torque is measured at the required temperature under cold or operating condition over the required tuning range by any suitable means. Measurements of starting, running and stop torque may be made.

A-3.1.1 *Precautions* — The rated maximum stop torque or force, including inertia forces, beyond which the parts of the tuning mechanism may sustain damage, must not be exceeded.

A-4. ELECTRONIC TUNING NON-LINEARITY

A-4.1 For this measurement, the frequency of oscillation is varied electronically over a small amplitude (for example, approximately 4 % of the modulation range) and the frequency deviation is measured by means of a suitable f. m. receiver (or spectrum analyzer). The oscillation frequency is slowly swept by varying the direct voltage applied to the frequency controlling electrode while the small superimposed modulating voltage is maintained constant. The deviation at the centre frequency S_0 and the maximum change in frequency deviation $\triangle S$ occurring over the swept range are noted. The ratio $\triangle S/S_0$ is a measure of the electronic tuning non-linearity.

A-5. ELECTRONIC TUNING RATE OR TUNING SPEED

A-5.1 A periodic signal of stated amplitude is applied to the tuning control and the frequency excursion of the device is measured, either (1) over a stated portion of the duration of one tuning cycle, or (2) over a complete tuning cycle.

A-5.2 The tuning rate can then be expressed in two ways : from (1) the quotient of frequency excursion by the stated periods of time, and from (2) the product of the total frequency excursion and the sweeping frequency (defined as the number of sweeps per second of the tuning control).

A-5.3 The two results may differ substantially.

A-5.4 At the stated amplitude, the sweeping frequency is slowly varied during the course of the measurement to determine the frequency at which the reduction of excursion or failure to tune takes place. The maximum tuning rate is determined from this frequency.

A-6. TUNING DISCONTINUITIES

A-6.1 In measuring tuning discontinuities, the frequency or power is measured over the frequency tuning range with an instrument of suitable resolution or precision. An abrupt change greater than a stated value shall be considered a discontinuity.

A-7. HYSTERESIS

A-7.1 This may be caused by either the mechanical properties of the tuning control itself, or the electrical characteristics of the tube being measured.

A-7.2 If hysteresis is present in the measurement of tuning sensitivity or range, a separate measurement shall be made for each direction of variation of the tuning control and, if these results are in substantial agreement, either result may be quoted. If the results are not in agreement, the direction of variation shall be stated.

A-8. MECHANICAL TUNING HYSTERESIS

A-8.1 The tube shall be operated under stated conditions at the reference frequency. The mechanical tuner is cycled as required over the complete frequency tuning range, then returned to the original mechanical setting point, and the frequency measured. Movement of the tuner spindle is then continued in the same direction to the end of the range, after which the tuner is again returned to the original mechanical setting point, at which a second measurement of frequency is made. The mechanical tuning hysteresis is expressed as the difference between these two frequencies.

A-9. ELECTRONIC TUNING HYSTERESIS

A-9.1 The tube is operated under stated conditions at the reference frequency. The electronic tuning control voltage is varied by the application of a suitable alternating sweep voltage of stated amplitude and frequency.

A-10. POWER HYSTERESIS

A-10.1 The output power of the tube is measured as a function of the electronic tuning control voltage, the power obtained as the voltage is increased being compared with the power obtained as the voltage is decreased.

A-10.1.1 *Degree of Power Hysteresis* — This may be measured in two ways as follows:

a) The ratio of (1) the maximum degree of power hysteresis expressed, as a difference, within a stated swept range to (2) the maximum power within that swept range, the result being expressed as a percentage, or

b) The ratio of (1) the highest power at which a stated degree of power hysteresis is reached as hysteresis increases to (2) the maximum power within the swept range, the result being expressed as a percentage or in dB.

A-10.1.2 *Range of Power Hysteresis* — This is expressed as the ratio of (1) the electronic tuning voltage range over which a stated degree of power hysteresis is exceeded to (2) a stated part of the sweep voltage range (for example, in reflex klystrons, the voltage range which provides oscillation over the full mode; in backward-wave oscillators, the voltage range required for tuning between stated frequencies). The result is expressed as a percentage.

A-11. FREQUENCY HYSTERESIS

A-11.1 The frequency of oscillation of the tube is examined as a function of the electronic tuning control voltage, the frequency obtained as the voltage is increased being compared with the frequency obtained as the voltage is decreased.

A-11.1.1 *Degree of Frequency Hysteresis* — This is measured as the absolute value of the difference between (1) the frequency obtained at a stated value of voltage as the voltage is increased through this value, and (2) the frequency obtained at the same value of voltage as the voltage is decreased through this value, the result being expressed in frequency units.

A-11.1.2 *Range of Frequency Hysteresis* — This is measured as the ratio of (1) the electronic tuning voltage range over which a stated degree of frequency hysteresis is exceeded to (2) a stated part of the sweep voltage range, the result being expressed as a percentage.

A-12. TUNER STOP TORQUE OF FORCE

A-12.1 The tuning control is tuned against an end stop. After a prescribed torque has been applied under stated conditions, no degradation of tuning control performance shall have occurred.

A-12.2 The measurement is repeated for each stop in the tuning system.

A-12.2.1 *Precautions* — Impact against the stop must be avoided.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2